



Case study on Risk and Benefit of Nitrogen-Use Efficient Water-Use Efficient and Salt-Tolerant Rice Breed in Nigeria

Seyi Ebun Adeboye¹, Shakirat O.A Ajenifujah-Solebo¹, Hannah Oluwakemi Oladipo², Dolapo Adetokunbo Adeshina¹

¹Department of Agriculture, National Biotechnology Development Agency Abuja, Nigeria

²Bioresources Development Centre, National Biotechnology Development Agency, Ilorin, Nigeria

Email of the corresponding author: oluseyiadeboye@yahoo.com

Received: 26 May 2022; Received in revised form: 18 Jun 2022; Accepted: 24 Jun 2022; Available online: 30 Jun 2022

©2022 The Author(s). Published by Infogain Publication. This is an open access article under the CC BY license

(<https://creativecommons.org/licenses/by/4.0/>).

Abstract— This study aimed to examine the perceived risks and benefits of Genetically Modified Organisms (GMO) in Nigeria with a focus on the agricultural technology of nitrogen use efficient, water use efficient, and salt-tolerant (NEWEST) Rice. A descriptive survey method was adopted for this study. Using a convenient sampling technique, 100 residents were drawn from the general population as respondents for this study. The questionnaire which was the instrument for data collection was administered to the respondents by the researcher personally. The results show that 58% of respondents will buy or eat NEWEST Rice. About 20% of the respondents would buy or eat NEWEST Rice because of its cheaper price, 15% for its nutritional benefits, and 13% for its better look and taste. Findings from this research also revealed that the perceived risks of NEWEST Rice are cross-pollination, adverse effects to human health, not looking and tasting good like organic rice, and antibiotic resistance in humans. The benefits identified include an abundance of rice supply to reduce poverty and starvation in Nigeria, improve the efficiency, profitability, and productivity of farmers, NEWEST Rice can minimize the use of water and fertilizer, better nutritional qualities, and reduction in pesticide use. This study, therefore, shows that NEWEST Rice will be averagely accepted (58%) in Nigeria. However, due to the intense debate on GM crops, there is a need for an improvement in the efficacy of scientific communication. There is also a need to create an informed, balanced public perception on the important issue of genetic engineering used in agriculture, even from the confined field trials, multi-location trials and use of GM crops in Nigeria.

Keyword—agricultural technology, benefits, genetically modified organisms, NEWEST rice, risks

I. INTRODUCTION

Agricultural biotechnology is the application of technology to agricultural systems. It has been recognized as a technology that can help farmers produce more from improved crop cultivars that are pest resistant, drought tolerant, water use efficient and efficient in nitrogen fixation [1]. The edible plant parts

can also be genetically modified to provide consumers with more micronutrients to correct for malnutrition and

diseases, especially in children and vulnerable groups. Agricultural biotechnology has been around for thousands of years. Farmers have engaged in what plant breeders now call selective breeding, by selecting and saving seed from those plants with the most desirable features. Over time, plant breeding has become more sophisticated, and now involves the deliberate crossing of different varieties or even species, including close wild relatives [2].

The discovery of DNA in 1954 led to breakthroughs in agricultural biotechnology. Techniques were developed that would enable individual genes that make up a DNA code to be modified to express or suppress important traits such as fruit yield, wood quality, fat content or disease resistance – a process known as genetic modification (GM). Although early applications of this technique involved the manipulation of a host's genome [3], later applications involved the transfer of genes between organisms that are not normally able to crossbreed, resulting in novel combinations. It is this ability to move genes across species barriers that give GMO important potential, but also renders it highly controversial.

However, not all forms of modern agricultural technology involve genetic modification; other, non-GM applications of agricultural biotechnology can assist in breeding plants as well as in the development and propagation of new crop varieties. These include tissue culture, molecular markers, diagnostic techniques and microbial products. Local farmers in Africa have benefited from tissue-culture technologies for banana, sugar cane, pyrethrum, cassava, and other crops [3].

GMOs have been developed that modify the quality of produce by increasing the nutritional value or providing more industrially useful qualities or quantities. The Amflora potato produces a more industrially useful blend of starches. Soybeans and canola have been genetically modified to produce more healthy oils. The first commercialized GM food was a tomato that had delayed ripening, increasing its shelf life [4].

Plants and animals have been engineered to produce materials they do not normally make. Pharming uses crops and animals as bioreactors to produce vaccines, drug intermediates, or the drugs themselves; the useful product is purified from the harvest and then used in the standard pharmaceutical production process [3].

There have been concerns about the risks and benefits of GMO technology across the world including Nigeria. Public concern over GMOs is centered in three areas: human health, environmental safety, and trade impacts [5].

GMO biosafety is also forcing both agriculture and food companies to appreciate GMO safety in their marketing decisions [6]. The adoption of GMOs in a given jurisdiction is a function of public GMO acceptance as well as the level of public trust of regulatory authorities based on the perceived risks and benefits [7].

Opponents of GMO technology have questioned their necessity in terms of agricultural productivity to feed the world [8]. They point to studies that have shown that current agricultural output far exceeds global calorie needs and that distribution, access, and waste are the key

limitations to feeding those who are hungry and not gross production per se [9]. The world population has exceeded 7 billion people and is forecasted to reach beyond 11 billion by 2100 [10]. The provision of adequate food supply for this booming population is an ongoing and tremendous challenge. The companies that develop GM seeds point to this challenge as the key rationale for their need, and they explain that GM seeds will help to meet the “feeding the world” challenge in several ways.

The risks and benefits of GMO are many and diverse. However, there is little argument over the ambiguous consequences of this comparatively new technology, and numerous critics noted the potential risks and benefits of GMOs as soon as they were launched [11][12][13]. Hence, the current researcher is examining the perceived risks and benefits of GMOs in Nigeria with a focus on the agricultural technology of the newest Rice.

Rice (*Oryza sativa*) is an important food crop in Africa. It is an ancient crop consumed as a healthy and staple food by more than half of the world's population. Rice production in Nigeria increases gradually over the years, with area expansion surpassing major Rice producing countries like Côte d'Ivoire and Sierra Leone [14]. However, demand in recent times has not been accompanied by a corresponding rise in production. This is attributed to wide- spread poverty, the dominance of the nation's agriculture by smallholders the use of relatively primitive tools for farm operations, lack of exposure to improved agricultural technology (improved seeds, fertilizers, and pesticides) and inadequate farm mechanization aids by the government [14].

Efforts to develop rice cultivars with stress-tolerant traits have resulted in the release of several varieties, but no known developed variety has combined the three traits of nitrogen-use efficiency, water-use efficiency and salt-tolerance, which are the major abiotic stresses to rice production in all the agro-ecologies in Africa. The new variety includes a trait for increased nitrogen use efficiency, which helps the plant take better advantage of the scant nitrogen found in Africa's often nutrient-poor soils. Soil nitrogen deficiencies limit yields on roughly 90 percent of the lands African farmers use for growing rice [14]. The engineered variety could also promote responsible fertilizer use by improving the crop's responsiveness to smaller doses of fertilizer. Rice varieties that are nitrogen use efficient, water use efficient and salt-tolerant (NEWEST) could therefore, boost yields by up to 30 percent in many regions, increasing farmers' climate resilience while also minimizing their use of fertilizer and water, reducing deforestation, and slowing the expansion of cultivated lands. As a complement to traditional

breeding programs, biotechnology has developed powerful tools that could help meet these ambitious agricultural and environmental goals. The objectives of this study are therefore to examine, the perceived risks of agricultural technology (GMO) in Nigeria, the benefits of agricultural technology (GMO) in Nigeria, and the level of acceptance of GMO rice in Nigeria.

II. MATERIAL AND METHOD

The study employed a descriptive design to assess the perceived risks and benefits of GMOs (a Case study of NEWEST Rice) among residents in various States, Nigeria [15]. Using a convenient sampling technique, 100 residents were drawn from the general population as respondents for this study. This is a statistical method of drawing representative data by selecting people because of the ease of their volunteering or selecting units because of their availability or easy access. The questionnaire which was the instrument for data collection was administered to the respondents by the researcher personally. It was divided into two (2) sections covering the research objectives of the study. Section A of the questionnaire covers the Bio-data of the respondents while section B covers the perceived risks and benefits of GMOs (Case study of newest Rice). The questionnaires were collected back from the respondents immediately after completion in order to avoid mutilation and to record a high response rate from the respondents. The data generated from this research was presented in a tabular form and analyzed using the descriptive statistics of frequency counts and percentage, the mean and standard deviation to enhance quick and easy understanding of the respondents' responses or opinions on the topic being researched on. The Statistical Package for the Social Scientists (SPSS) and MS Excel 2016 was employed to analyze the obtained information statistically from the questionnaires.

III. RESULTS AND DISCUSSION

A total of 100 questionnaires were administered but the researcher was able to retrieve 93 questionnaires back and all were considered valid for this study. This represents a 93% response rate in this study.

3.1. Socio-demographic characteristics of the respondents

The results of the socio-demographic characteristics of the respondents as presented in Table 1 show that out of 93 respondents to the questionnaires, 49 (52.7%) were females. In contrast, 44 males which constitute 47.3% of the respondents were males. The majority of the respondents 31(33.3%) were within the age group 46 years

and above, followed by age group 36-45 years 29(31.2%). The least number of respondents 9(9.7%) were within the age group 15-25 years. The result in table 4.1 shows that 35 respondents representing 37.6% are single, while 53 respondents representing 57% are married and only five respondents representing 5.4% are divorced or separated. The results further revealed that only two respondents representing 2.2% had attained a primary level of education, two respondents representing 29% have achieved secondary level of education, and 64 respondents representing 68.8% of the total respondents have attained BSc/MSc. Hence, the respondents that have BSc/MSc level qualifications have the highest frequency while the respondents that have attained primary level of education have the lowest frequency.

3.2 Level of acceptance of GMO rice in Nigeria

The respondents were asked if they have heard about NEWEST Rice and only 35% said they have heard about it. The 65% that have not heard about NEWEST Rice were briefly educated about it. They were told what NEWEST Rice means and its status in Nigeria. The result in Table 2 shows that 58% of respondents would accept, buy or eat NEWEST Rice, while 43% would not. This is similar to the findings of Eneh *et al.* [16] who reported that 58% of respondents in Enugu metropolis Nigeria are willing to accept GM foods. Al-Khayri and Hassan [17] also reported that 48% of consumers will buy or eat GM foods in Saudi. The difference between the acceptance and non-acceptance of NEWEST Rice as observed in this study is not much. Therefore, it can be presumed that NEWEST Rice will be averagely accepted by the Nigerian populace.

Despite the acceptance of NEWEST Rice in Nigeria, some people are still not in agreement with the acceptance of GM crops in Nigeria. Some argue against the principles of genetic modification because of ethical or religious beliefs. However, the main arguments relating to how GM is actually applied. Proponents for GMO claim that through GM crops, trees, livestock and fisheries, biomass (including food and fiber) production can be enhanced while indirectly reducing environmental impacts, for example, through less use of pesticides or fertilizers. They also oppose that GMO can improve the nutritional value of many crops, or reduce the possible food safety risks posed by crops such as cassava [14].

According to Eneh *et al.* [16], certain people's view GM foods production and processes as not 100% safe which is a reason for it's none acceptance. However, others claim that the scientific knowledge on potential risks and benefits of GMO is elementary, the net gains in agricultural productivity and the potential profits are both unclear, and the health and environmental risks are little

understood. Antagonists claim that the potential direct effects of GMO crops on biodiversity and human health are unknown and are potentially so damaging that a moratorium must be placed on all GMO products until more information is available. Others emphasize the indirect impacts that GMO crops can have on traditional farming patterns, conservation efforts, livelihoods and trade [14].

More so, most people disapproval to genetically modified (GM) food and crops are caused by the public's misunderstanding of the risks, what comes to their mind is the risk associated with it without really putting much thought that the benefit is vast and no unique risk have been identified.

As presented in Table 2, 20% of the respondents would buy or eat NEWEST Rice because of its cheaper price, 15% for its nutritional benefits, 13% for its better look and better. This is in accordance to the findings of Eneh *et al.* [16] who found that 38.3% would eat or buy GM foods for nutritional benefits. Ebuehi & Ailohi [18] however found that a higher number of students (75.6%) were willing to buy or eat GM foods for better nutritional characteristics.

The respondents were also asked their opinion if Nigeria Government should legalize the production and importation of GM foods in Nigeria, 56% said Nigeria should, while 34% thought Nigeria should not. According to the report of Global Biotech [19], developing countries are fast accepting agricultural technology hoping to lessen hunger and poverty. These countries account for forty percent of the global farmlands used for GM crop cultivation including Nigeria.

Although, there are reasons, controversies, disagreement, and hesitation about the acceptance of genetically modified foods in Nigeria, the introduction of GM crops to Nigeria as one of the strategies to address food security crisis has gained increasing momentum because it has the potential to improve crops appearance, taste, nutritional quality, drought tolerance, insect and disease resistance [20]. The embracement and adoption of GM foods by the Nigerian Government would provide sustainable food security and, increased productivity in the agricultural sector that would lead to the improved socioeconomic status of Nigerian farmers and enhanced national economic prosperity.[4].

Table 1: Socio-Demographic Characteristics of Respondents

Gender	Frequency	Percentage (%)
Male	44	47.3
Female	49	52.7
Total	93	100
Age Range		
15 – 25	9	9.7
26 – 35	24	25.8
36 – 45	29	31.2
46 and above	31	33.3
Total	93	100
Marital Status		
Single	35	37.6
Married	53	57.0
Divorced/Separated	5	5.4
Widow	-	-
Total	93	100
Level of Education		
Primary School Certificate	2	2.2
SSCE	27	29.0
BSc/MSc	64	68.8
Total	93	100

Table 2: The level of acceptance of GMO Rice in Nigeria

SN	Questions	Yes %	No %	Not %	Sure
1	Have you heard about NEWEST Rice?	35	65	0	
2	Are you willing to accept, eat or buy the NEWEST Rice	58	43	0	
3	Reason for accepting NEWEST Rice				
	*Nutritional benefits	15			
	*Look or taste better	13			
	*Cheaper price	20			
	*Lower risks of pesticide poison	10			
4	Should the FG legalize the production and importation of GM foods in Nigeria	56	34	10	

3.3 Perceived Risks of Agricultural Technology (GMO) in Nigeria

The results of this study reveal the perceived risks of agricultural technology (GMO) of the NEWEST Rice in Nigeria. The risks were identified as cross pollination, adverse effect to human health, not looking and tasting good like organic rice and antibiotic resistance in humans (Table 3). As revealed in Table 3, majority of respondents (69%) are of the opinion that NEWEST Rice is artificial and may not taste good like organic Rice. This is consistent with the report of Eneh *et al.* [16] who reported that 65% of respondents believed that GM foods were artificial. Some people believe that GM foods were artificial and may not taste and look good probably because of their ignorance about the composition and benefits of new GM foods compared with non-GM foods.

This study shows that 65% of respondents believed that NEWEST Rice can affect human health negatively. Ebuehi & Ailohi [18] similarly reported that 58.9% of respondents are concern that GM foods could cause adverse effects to human health.

This shows that there are still many people who hold anxieties about the potential risks of GM foods to human health. For some this is related to whether transgenesis itself causes unintended consequences, while for others it

is concerns around the traits that are possible using GM [5]. Some criticize the use of antibiotic resistance as markers in the transgenesis procedure and that this can facilitate antibiotic resistance development in pathogens that are a threat to human health. Many critics of GM crops express concerns about allergenicity [7].

GM crops have also been criticized for promoting the development of pesticide resistant pests [21]. The development of resistant pests is most due to the overuse of a limited range of pesticides and overreliance on one pesticide. Although the deregulation of GM crops includes extensive assessments of possible human health impacts by competent authorities, there are still many who hold concerns about the potential risks to human health of GM crops. For some this is related to whether transgenesis itself causes unintended consequences [22], while for others it is concerns around the traits that are possible using GM [23]. Other concerns that have been raised regarding GM crops as reported by some researchers include the effects of transgenic on the natural landscape, significance of gene flow, impact on non-target organisms, progression of pest resistance, and impacts on biodiversity [20]. Again, many of these concerns may be more a function of the impacts of simple and broad-scale farming practices facilitated by GM crops rather than GM crops as such.

Table 3: The perceived risks of GMO Rice in Nigeria

SN	Questions	Yes %	No %	Not %	Sure
1	NEWEST Rice can affect human health negatively	65	25	10	
2	It can cause harm to the environment	39	43	18	
3	The outcome of cross-pollination is one of the risks of agricultural technology (GMO Rice)	61	35	4	

4	NEWEST Rice is artificial and may not taste good like organic rice	69	28	3
5	It can lead to antibiotic resistance in humans	54	41	5
6	One of the negative outcomes of GM Rice is pest resistance	45	40	15
7	It can cause genetic mutation in humans	40	36	24

3.4 Benefits of Agricultural Technology (GMO) in Nigeria

The results also reveal the benefits of agricultural technology (GMO) Rice in Nigeria as presented in table 4. Some of the identified benefits include abundance of rice supply to reduce poverty and starvation in Nigeria, improve the efficiency, profitability and productivity of farmers, NEWEST Rice can minimize the use of water and fertilizer, better nutritional qualities and reduction in pesticide use. The majority of the respondents (75%) believed that NEWEST Rice will lead to adequate rice supply for the Nigerian populace. This result is in affirmation to the report of [24] that GM foods provides abundant food supply, as global food insecurity will not fade away without this new technology. This is in accordance to the proposition of some scientists that a second Green Revolution including the use of modified crops is needed to provide sufficient food [25]. Commercial GM crops are known to have traits that reduce yield loss from insect pressure or weed interference thereby making food widely available to consumers [26].

According to United Nations Department of Economics and Social Affairs [27], the world population has exceeded 7 billion people and is forecasted to reach beyond 11 billion by 2100. The provision of an adequate food supply for this booming population is an ongoing and tremendous challenge. Therefore, agricultural technology is essential to feed growing world population.

According to Table 4, 64% of the respondents were of the opinion that NEWEST Rice would fundamentally improve the efficiency, profitability and productivity of rice farmers in Nigeria. This is true as agriculture always provides

opportunities to turn rural poverty and stagnation into development [28]. But acceptance and broad usage of genetically engineered foods is needed to achieve this. [29]. The economic value of GM food's to farmers is one of its major benefits in developing nations [30]. The Economics comprehensive study in 2012 established that GM crops increased farm incomes all over the world by \$14 billion in 2010 and with over half this amount going to farmers in developing countries [31].

In addition GM seed companies argue that the adoption of GM crops helps to reduce the application of pesticides, which has a direct impact on the sustainability of the cropping systems as well as profitability for farmers [32]. Some respondents (52%) also believed that NEWEST Rice can minimize the use of water and fertilizer. This is one of the advantages of NEWEST Rice, it is expected to solve the problem of water and fertilizer for rice farmers.

Table 4 also shows that 58% of respondents believed that GM Rice will contain better nutritional qualities. This result was close to the findings of Eneh *et al.* [16] where 75% of people resident in Enugu metropolis Nigeria thought that GM foods enhance nutritional value. However, this result is contrary to the report of Ebuehi & Ailohil [18] who found that 43.3% of University of Lagos students believed that GM foods have more quality nutrients and better health benefits compared with non-GM foods. The difference could be attributed to some people disbelieve in GM foods or ignorance about the relatively new GM foods compared with non-GM foods.

Table 4: Benefits of Agricultural Technology GMO Rice in Nigeria

SN	Questions	Yes %	No %	Not Sure %
1	NEWEST Rice will lead to adequate rice supply	75	15	10
2	NEWEST Rice would fundamentally improve the efficiency, profitability and productivity of farmers	64	24	12
3	NEWEST Rice can minimize the use of water and fertilizer	52	33	15
4	It can increase climate resilience and therefore boost productivity	44	32	24
5	NEWEST Rice may look or taste better than organic Rice	40	32	28
6	It has better nutritional qualities	58	36	6
7	NEWEST Rice would reduce pesticide use	51	35	14

IV. CONCLUSION

As revealed by this study, the perceived risks of NEWEST Rice are cross pollination, adverse effect to human health, not looking and tasting good like organic rice and antibiotic resistance in humans. The benefits identified include an abundance of rice supply to reduce poverty and starvation in Nigeria, improve the efficiency, profitability, and productivity of farmers, NEWEST Rice can minimize the use of water and fertilizer, better nutritional qualities and reduction in pesticide use. This study, therefore, shows that NEWEST Rice will be averagely accepted in Nigeria. However, due to the intense debate on GM crops, there is a need for an improvement in the efficacy of scientific communication, which could have a significant impact on the future of agricultural genetic engineering. There is a need to create an informed, balanced public perception on the important issue of genetic engineering used in agriculture, even from the confined field trials, multi-location trials, and use of GM crops in Nigeria.

REFERENCES

- [1] Sakakibara, K. & Saiko, K. (2006). Review: Genetically modified plants for the promotion of human health. *Biotechnology Letters*, 28, 1983–1991.
- [2] Dordrecht, The Netherlands: Kluwer. Yuan, D., Bassie, L., Sabalza, M., Miralpeix, B., Dashevskaya, S., Farre, G., ... Christou, P. (2011). The potential impact of plant biotechnology on the millennium development goals. *Plant Cell Reports*, 30, 249–265.
- [3] Ellstrand, N. (2003). Current knowledge of gene flow in plants: Implications for transgenic flow. *Philosophical Transactions of the Royal Society B: Biological Science*, 358(1434), 1163–1170.
- [4] Gbarada, O. (2017). Genetically Modified Foods (GMOs) and Its Environmental Conflict Situation in Nigeria. *American Journal of Environmental Policy and Management*, 3(5) 31-38
- [5] Van Acker, R. C., Brule-Babel, A. L., & Friesen, L. F. (2004). Intraspecific gene movement and create environmental risk: The example of Roundup Ready® wheat in western Canada. In B. Breckling & R. Verhoeven (Eds.), *Risk, hazard, damage—specification of criteria to assess environmental impact of genetically modified organisms* (pp. 37–47).
- [6] Blaine, K., & Powell, D. (2001). Communication of food-related risks. *AgBioForum*, 4, 179–185.
- [7] Fischer, K., Ekener-Petersen, E., Rydhmer, L., & Edvardsson Björnberg, K. (2015). Social impacts of GM crops in agriculture: A systematic literature review. *Sustainability*, 7, 8598–8620.
- [8] Gilbert, N. (2013). A hard look at GM crops. *Nature*, 497, 24–26.
- [9] Mann, S. (2015). Is “GMO free” an additional “organic”? On the economics of chain segregation. *AgBioForum*, 18, 26–33.
- [10] United Nations Department of Economic and Social Affairs, Population Division. (2017). World population prospects: The 2017 revision, key findings and advance tables. Retrieved from https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf.
- [11] Mannion, A. M. (1995a). Biotechnology and environmental quality. *Progress in Physical Geography*, 19, 192–215.
- [12] Mannion, A. M. (1995b). Agriculture and environmental change: Temporal and spatial dimensions. Chichester, U.K.: John Wiley.
- [13] Mannion, A. M. (1995c). The three Bs: Biodiversity, biotechnology and business. *Environmental Conservation*, 22, 201–210.
- [14] Adedeji, T. O., Nosiru, M. O., Akinsulu, A. A., Ewebiyi, I. O., Abiona, B. G. & Jimoh, T. S. (2013). Adoption of new rice for Africa (NERICA) technology in Ogun State, Nigeria. *Journal of Development and Agricultural Ecology*, (9), 365-371.
- [15] wikipedia.org/wiki/States_of_Nigeria
- [16] Eneh, O. C., Chineme, A. Eneh, S. & Chiemela, N. (2016). Food consumer perception of genetically modified foods in Enugu metropolis, Nigeria. *Jokull Journal*, 66(4), 1-16
- [17] Al-Khayri, J.M and Hassan, M.I. (2012). Socio-Demographic factors influencing public perception of genetically modified foods in Saudi Arabia. *Ameri J. Food Technol.*, 7(3), 101-112.
- [18] Ebuehi, O. M. and Ailohi, O. L. (2012). Genetically Modified (GM) Foods/Organisms: Perspectives of Undergraduate Medical and Dental Students of the College of Medicine, University of Lagos, Lagos, Nigeria. *Food and Public Health*, 2 (6), 281-295.
- [19] Global Biotech (2007). Area Surges Past 100 Million Hectares on 13 Percent Growth: International Service for the Acquisition of Agri. Biotech Applications ISAAA (US). Available online from <http://www.bionity.com/en/news/61027/>
- [20] Prakash, D. Verma, S. Bhatia, R. & B. N. Tiwary. (2011). “Risks and Precautions of Genetically Modified Organisms”. *International Scholarly Research Network, ISRN Ecology*, Volume 2011, Article ID 369573, 13 pages.
- [21] Dale, P. J., Clarke, B., & Fontes, E. M. G. (2002). Potential for the environmental impact of transgenic crops. *Nature Biotechnology*, 20(6), 567–574.
- [22] Domingo J. L. (2016). Safety assessment of GM plants: An updated review of the scientific literature. *Food and Chemical Toxicology*, 95, 12–18.
- [23] Herman, E. M. (2003). Genetically modified soybeans and food allergies. *Journal of Experimental Botany*, 54, 1317–1319.
- [24] Mohamed, K. (2013). “Africa Environment Outlook 2: Our Environment, Our Wealth.”
- [25] Kiers, E. T.; Leahey, R. R. B.; Izac, A.-M.; Heinemann, J. A.; Rosenthal, E.; Nathan, D. & Jiggins, J. (2008). "ECOLOGY: Agriculture at a Crossroads". *Science* 320 (5874): 320–1. doi: 10.1126/science.1158390. PMID 18420917.

- [26] Raney, T. & Pingali, P. (2007). "Sowing a Gene Revolution". Scientific American. Retrieved October 26, 2014.
- [27] United Nations Department of Economic and Social Affairs, Population Division. (2017). World population prospects: The 2017 revision, key findings and advance tables. Retrieved from https://esa.un.org/unpd/wpp/Publications/Files/WPP2017_KeyFindings.pdf.
- [28] Barrows G., Sexton S. and Zilberman, D. (2014). "Journal of Economic Perspectives" Volume 28, Number 1—Winter 2014—Pages 99–120.
- [29] Areal, F. J., Riesgo, L. & Rodríguez-Cerezo, E. (2012). Economic and agronomic impact of commercialized GM crops: A metaanalysis. *The Journal of Agricultural Science*, 151,(7)33. doi: 10.1017/S0021859612000111.
- [30] Blaine, K., & Powell, D. (2001). Communication of food-related risks. *AgBioForum*, 4, 179– 185.
- [31] Lynas, Mark (4 November 2010). "What the Green Movement Got Wrong: A turncoat explains". The Daily Telegraph. Retrieved 5 November 2010.
- [32] Nazarko, O. M., Van Acker, R. C., & Entz, M. H. (2005). Strategies and tactics for herbicide use reduction in field crops in Canada: A review. *Canadian Journal of Plant Science*, 85, 457–479.